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Satellite Catalog Renumbering
What does that mean and should I be worried?

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Prepared for:

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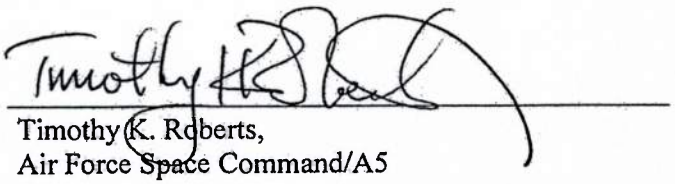

Timothy K. Roberts,
Air Force Space Command/A5

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14. ABSTRACT

Satellites are vital to our everyday life. Whether in support of transportation, commerce, emergency services, or communication, knowledge of where the satellite is located is essential to proper execution of these functions. The Joint Space Operating Center maintains a catalog of all earth satellites and distributes the locations via a fixed-format message called the "Two Line Element Set". Because of growth of the number of objects in the satellite catalog, it is expected that the fixed format will be insufficient to accommodate the satellite identifying number perhaps as soon as a few years from today. It is essential that Aerospace and our customer begin to plan and budget for needed software changes to accommodate a new, as yet undetermined format.

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Abstract

Satellites are vital to our everyday life. Whether in support of transportation, commerce, emergency services, or communication, knowledge of where the satellite is located is essential to proper execution of these functions. The Joint Space Operating Center maintains a catalog of all earth satellites and distributes the locations via a fixed-format message called the "Two Line Element Set". Because of growth of the number of objects in the satellite catalog, it is expected that the fixed format will be insufficient to accommodate the satellite identifying number perhaps as soon as a few years from today. It is essential that Aerospace and our customer begin to plan and budget for needed software changes to accommodate a new, as-yet-undetermined format.

Please note: The following material is an excerpt from The Aerospace Corporation TOR-2013-00021 (distribution limited).

Contents

Satellite Catalog Renumbering

What does it mean and should I be worried?

Beginning with the launch of the first satellite in 1957, the U.S. Government began keeping a database of every manmade object in space (payloads, rocket bodies, and launch debris). Each object is assigned a unique sequential number. Both historical information such as launch site, country of origin and launch date as well as current satellite location information are keyed to this number. There are over 16,000 satellites now in orbit while many more than this have fallen back to the Earth. A total of over 38,000 objects have been cataloged.

Satellite data is periodically updated by the Joint Space Operations Center (JSpOC) on what is called a "Two Line Element Set" (TLE). Using this data in the proper formulas allows us to predict when the satellite will be overhead and where to point our antenna to exchange data. TLEs are the primary format for distributing satellite location information world-wide for the U.S. government, civilians, and international agencies.

Satellites are vital to our everyday life. Whether transportation, commerce, emergency services, or communication – somewhere in the process each of these capabilities must use a two line element set to know where the satellite is in order to obtain needed data.

The TLE is a standardized format with data in assigned locations. Computers are programmed to expect data to be in the assigned field. The satellite number is a 5 digit field. 99,999 is the largest number that can be used. However, numbers larger than 70,000 are reserved for temporary processing such as new launches, uncorrelated tracks, and satellite breakup processing. There is some current consideration to also reserve the 60,000 series of numbers. So for planning purposes, we must assume that the 5 digit limit of numbers will be exhausted when the catalog numbering reaches 60,000.

But when will this occur? If we assume a growth rate of 4% per year, then the limit could be reached in about 10 years, whereas an 8% growth rate will reach the limit in 5 years. Between 2007 and 2009 the catalog growth rate was approximately 6% annually. Three debris producing events were responsible for this unusual growth. The Chinese tested an anti-satellite weapon and totally fragmented a defunct weather satellite, the Iridium communications satellite inadvertently collided with a no longer operational Russian Cosmos satellite, and the U.S. shot down a disabled satellite containing potentially dangerous fuel.

Although these were unusual events resulting in an unusual catalog growth rate, there are new more sensitive tracking sites scheduled to come on line which could produce a similar or even larger growth rate. The Space Surveillance Telescope will have much improved sensitivity and is expected to track and catalog numerous small objects that are now in orbit but are not able to be tracked. The Government is procuring an S-band surveillance radar system that is expected to increase the catalog to over 100,000 objects due to its increased ability to track small objects a few centimeters in size.

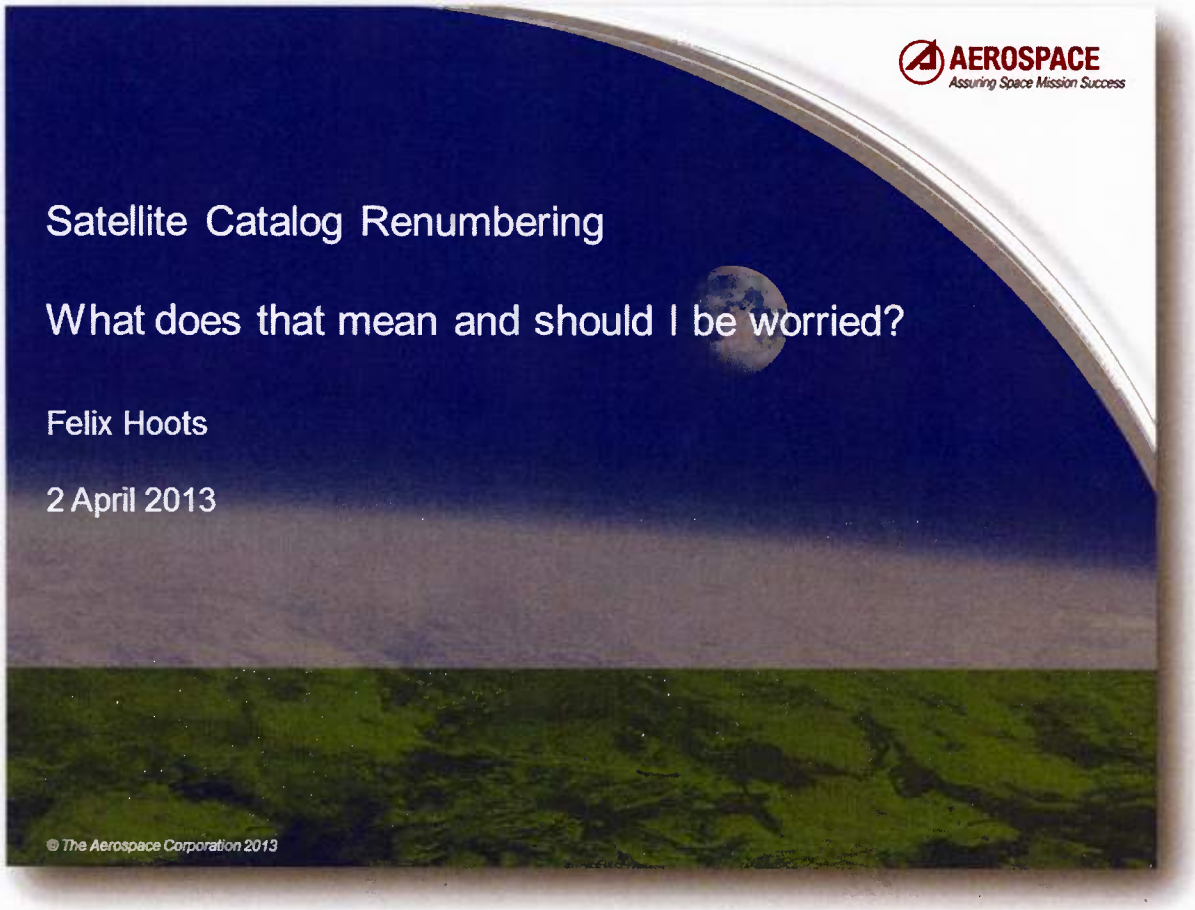
One idea for prolonging the availability of 5 digit numbers is to have the new tracking sites utilize a 9 digit numbering system for small pieces of debris while continuing to use the scarce 5 digit numbers for the non-debris objects. Thus, if you only deal with operational satellites, the current 5 digit format may be adequate until 2019 or beyond. However, if you are concerned with collision avoidance of your satellite with all known objects, then you will need to deal with 9-digit numbers as soon as they begin to be utilized for debris.

The Satellite Catalog Renumbering Working Group has been determining a path forward and is finalizing their report now. The earliest that a 9 digit element set could be produced is the beginning of FY15. Details of the format are unknown at this time. However, a change to the satellite ID data field to 9 digits

will force a change to the entire record format. Therefore, it is expected that several other limitations in the current format such as a two digit year and limited precision in the data fields will be rectified as well.

Absent specific information, you should look at the tools and the data sources you use and see what will have to be modified if the format changes. Estimate the amount of code that will need to be modified as well as the cost and time required. Keep in mind that this is like Y2K in that every satellite related computer routine will need to be examined. You should be telling your customers about this as well. The bottom line is to start planning and budgeting for this for your program NOW.

Appendix A. *Satellite Catalog Numbering* Briefing Charts



This Briefing Will Address the Questions . . .

- Who cares?
- Who *should care?*
- Why should they care?
- What is the impact -- and to what extent?

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What is the Satellite Catalog?

- Beginning with the launch of the first satellite, the US Government began keeping a database of every manmade object in space
  - *Payloads*
  - *Rocket bodies*
  - *Launch debris*
- Each object is assigned a unique sequential number
- Information about the satellite is keyed to this number
  - *Historical data: country, launch site, launch date, mission, etc*
  - *Dynamical data: current information on orbit characteristics*
- There are currently about 16,000 objects in orbit
  - *Many more than this have been launched but have since fallen back to the earth*

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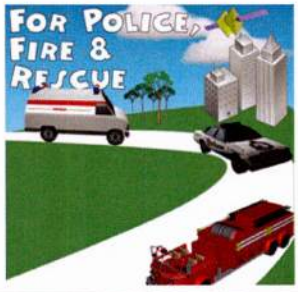
Satellites Are Vital to Our Everyday Life



Courtesy of FCC Satellite Learning Center.

Somewhere in the process, each of these capabilities had to use satellite position information to know where the satellite was.

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So Where Do We Point to Get Our Data Link?

- Satellite Data is periodically updated by the Joint Space Operations Center (JSpOC)
- They provide the data for each satellite on what is called a "Two Line Element Set" (TLE)

```
1 19479U 93036ADR 09363.58083572 +.00000332 +00000-0 +87177-4 0   00
2 19479  62.8084  26.7533 0636028 357.0736  83.1973 13.69682138   00
```

Satellite number, International designator, Epoch time, drag parameters
Inclination, right ascension, eccentricity, argument of perigee, mean anomaly, mean motion

- Using this data in the proper formulas allows us to predict when the satellite will be overhead and where to point our antenna to exchange data
- TLEs are the primary format for distributing satellite location information world-wide, for the US government, civilians, and international agencies

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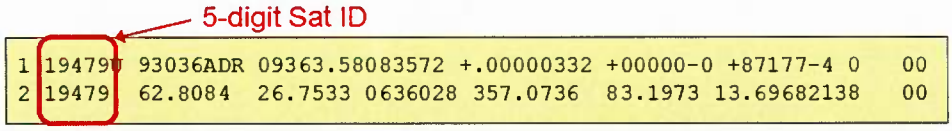
So What's the Issue with Satellite Numbers?

- The Two Line Element Set is a standardized format with data in assigned locations
- Computers are programmed to expect data to be in the assigned field
- The satellite number is a 5 digit field
  - *99,999 is the largest number that can be used*
  - *Numbers above 70,000 are reserved for special use*
    - Current recommendation would reserve 60,000 series as well
- Depending on the rate of satellite population growth, we could reach the limit of the 5 digit number within the next 5 to 10 years



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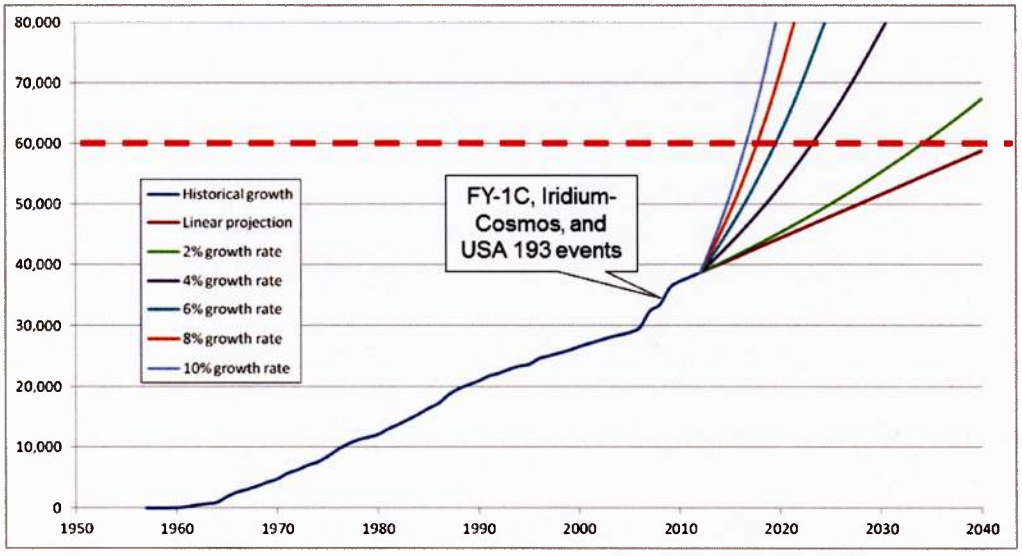
So . . . How Soon Will We Run Out?



Maybe as early as 2015, depending on growth rate!

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So Which Curve Do I Believe?

It depends of what you use the catalog for

- Good news
  - *New more sensitive sensors will be coming on line*
    - The SST optical system
    - The S band radar space fence
  - *New small objects only tracked by these sensors will get 9 digit number*
  - *New larger objects trackable by majority of sensors will get 5 digit number*
  - *This delays running out of 5 digit numbers for larger non-debris objects*
- Bad news
  - *The small objects are just as deadly if they run into you*
- And so . . .
  - *If you are just dealing with predicting operational satellites, 5 digits may last you until 2019 or beyond*
  - *If you are worried about collision avoidance, you may have to deal with a 9 digit number sooner*

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So . . . what are we going to do?

- Satellite Catalog Renumbering Working Group (SCRWG) has been assessing problem and solution options
  - *"Define catalog renumbering plan . . ."*
  - *"Identify full scope of systems affected including . . . space surveillance data users"*
  - *"Develop and propose mitigation strategies for all affected entities"*
- Status of SCRWG
  - *Recommend 9 digit satellite numbers with a hybrid catalog*
  - *Reserve 60,000 series for special use*
  - *Briefing to "Astrodynamics Innovation Committee Senior Steering Group" planned for no earlier than 22 April for decision*
  - *Target completion in FY19*

This is as far reaching for space systems as the Y2K modification effort more than a decade ago

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What will the new data format look like?

- Nobody knows!
- What do we think it will be?
  - *It will have 9 digit satellite number*
  - *It will probably fix other shortfalls*
    - 4 digit year instead of 2 digit year
    - More precision on orbital elements
    - No more "funky" formats like implied decimal point
  - *Exact format will be worked out by a TBD working group*
- A change to the Sat ID data field to 9 digits will force a change to the entire record format

I wish I knew!

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Other Satellite Data Will Be Affected

e.g. Vector Covariance Message (VCM) for high accuracy catalog

```
<> SP VECTOR/COVARIANCE MESSAGE - V2.0
<>
<> MESSAGE TIME (UTC):                                  CENTER:ASpace
<> SATELLITE NUMBER: 11111                        INT. DES.:
<> COMMON NAME:
<> EPOCH TIME (UTC): 2013  55 (24 FEB)  5:49:30.000  EPOCH REV:    54
<> J2K POS (KM):          0.00000000       0.00000000       0.00000000
<> J2K VEL (KM/S):    0.000000000000   0.000000000000   0.000000000000
<> ECI POS (KM):     -45263.84292597    3737.04611451      75.61831448
<> ECI VEL (KM/S):   -0.403921066274  -2.816990252398  -0.048083450065
<> EFG POS (KM):          0.00000000       0.00000000       0.00000000
<> EFG VEL (KM/S):    0.000000000000   0.000000000000   0.000000000000
<> GEOPOTENTIAL: EGM-96 36Z,36T  DRAG: JAC70/MSIS90  LUNAR/SOLAR: OFF
<> SOLAR RAD PRESS: OFF  SOLID EARTH TIDES: OFF  IN-TRACK THRUST: OFF
<> BALLISTIC COEF (M2/KG):  0.000000E+00 BDOT (M2/KG-S): 0.000000E+00
<> SOLAR RAD PRESS COEFF (M2/KG):  0.000000E+00  EDR(W/KG):  0.00E+00
<> THRUST ACCEL (M/S2):  0.000000E+00  C.M. OFFSET (M):  0.000000E+00
<> SOLAR FLUX: F10:    0  AVERAGE F10:    0  AVERAGE AP:    0.0
<> TAI-UTC (S):  0  UT1-UTC (S):  0.00000  UT1 RATE (MS/DAY):  0.000
<> POLAR MOT X,Y (ARCSEC):  0.0000  0.0000 IAU 1980 NUTAT: 103 TERMS
<> TIME CONST LEAP SECOND TIME (UTC):
<> INTEGRATOR MODE: AWS          COORD SYS: J2000  PARTIALS: ANALYTIC
<> STEP MODE: TIME  FIXED STEP: ON   STEP SIZE SELECTION: MANUAL
<> INITIAL STEP SIZE (S):           ERROR CONTROL:
<> VECTOR U,V,W SIGMAS (KM):          18.2956      3.8418      4.2083
<> VECTOR UD,VD,WD SIGMAS (KM/S):      0.0057      0.0016      0.0007
<> COVARIANCE MATRIX (EQUINOCTIAL ELS): ( 6x 6) WTD RMS:  0.46864E+01
<>  0.64017E-06  0.14053E-05  0.31371E-05 -0.31398E-05 -0.69800E-05
<>  0.15546E-04  0.96309E-11  0.23831E-10 -0.51507E-10  0.87022E-14
<> -0.18501E-07 -0.40113E-07  0.89945E-07 -0.29120E-12  0.29723E-08
<>  0.67292E-07  0.14976E-06 -0.33353E-06  0.11734E-11 -0.54125E-08
<>  0.12154E-07  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
```

Embedded Sat ID

ALL software that deals with the actual location of a satellite will be affected

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What will happen next and when?

- The SCR WG is finalizing their report now
- Briefed up to 2 star level (Spring 2013)
- Decision to execute (Spring 2013)
- Actions to implement the 9-digit format will be finalized by the beginning of FY14 (note that SCRWG "hopes to have the format agreed to six months earlier and to have spent the intervening time outlining the implementation plan across sensors, users, etc."
- Initial insertion/validation (Space Fence, JMS) - NLT Dec 2013
- The earliest that a 9 digit element set could be produced is the beginning of FY15 (this is consistent with "getting off SPADOC by the end of FY14")

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Absent specific information, what should you do?

- Look at the tools and the data sources you use and see what will have to be modified if the format changes
- Estimate the amount of code that will need to be modified
- Keep in mind that this is like Y2K
  - *You have to look at every routine just to make sure*
  - *Could be simple print statements that won't fit anymore*
- Determine how long this will take to modify and test
- You should be telling your customers about this as well

- *Space Fence and JMS will starting using/producing 9-digit satnos as they come on-line.*
- *Adoption will occur over a five year period starting in FY14. So users and customers should be looking at sooner rather than later.*
- *This will nominally happen in FY19 but individual debris pieces may have to be accommodated as **early as 2015!***

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Bottom Line

- Satellite catalog information is distributed in a format with maximum satellite number limited to a 5 digit field
- Pending addition of more sensitive Space Surveillance Network (SSN) sensors is expected to result in catalog growth beyond the current number range
- The Government is considering options/formats for data distribution which will accommodate satellite numbers beyond 5 digits
- Such a change will have a far reaching effect in the space community much like the Y2K issue
- We must begin to assess the effect on our tools and databases and prepare to make changes once the Government defines the new data formats
  - **Start planning and budgeting for this for your program NOW**

Yes, you should be worried!

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